September 2006 Technical Series 06-107

The ēKOCOMFORT™ Field Assessment Program

INTRODUCTION

CMHC, in partnership with Natural Resources Canada (NRCan), evaluated the performance of a new type of HVAC (heating-ventilation-air conditioning) system in a two-year project.

The ēKOCOMFORT™ system combines space heating, water heating and ventilation in a packaged, integrated unit. A federal government-industry consortium developed performance requirements and identified and licensed integrated products that meet target specifications. Independent Canadian manufacturers developed and manufactured prototypes or early production samples that had not met all the ēKOCOMFORT™ requirements.

PROJECT OBJECTIVES

The objectives of the project were to provide timely and effective reporting to specific manufacturers, the ēKOCOMFORT consortium, CMHC and NRCan that would:

- Characterize the performance of ēKOCOMFORT products in energy consumption, space conditioning, domestic hot water and ventilation performance
- Assess the degree to which the products met homeowners' needs in capacity, indoor environment, user friendliness, operational issues, comfort, use and maintenance
- Assess product reliability
- Estimate the extent to which laboratory test results of the products were reflected in actual field performance.

THE RESEARCH PROGRAM

The project was developed with an ambitious and dynamic structure. A web of relationships between various entities was built before and during the project to develop linkages that would support the development of market infrastructure for this new class of products as they were beginning to be commercialized. This approach was designed by the government stakeholders to encourage the building of an overall project infrastructure and to contribute to the creation of infrastructure elements, such as standardized installation, commissioning, planning and documentation.

The project included up to 10 sites for each manufacturer, with an audit carried out at all of the sites. In addition, each manufacturer designated one of its sites as a monitored site for installation of a monitoring package and more detailed analysis. Some of the sites were "non-arms length" sites at which there was a family relationship between the manufacturer and the owner of the test site.

The manufacturers provided installation reports for completed installations that they wanted to include in the project. The reports were based on a template that was developed and supplied by the ēKOCOMFORT consortium. The installation reports included a variety of information for each installation, including a site description, the manufacturer's commissioning measurements and contact details for each site.

After the reports were received and reviewed, arrangements were made for site audits. The site audits included inspecting the installations, speaking with the homeowners, supplying site logbooks (and reviewing them in subsequent audits) and measuring the performance of the systems. The key objectives of the audits were to investigate and document the way the products had been installed, obtain performance snapshots of their operation and assess the ability of the systems to meet the customer's needs.

Homeowner-occupant, manufacturer and installer surveys were developed and used to investigate:

- Reasons for selecting the integrated systems
- System installation and operational issues
- The system's ability to provide the required system outputs
- System reliability issues and maintenance requirements.

The project started in the fall, 2002 and ended in the summer, 2004. Field assessments of the installed products started as soon as the manufacturers said that the installations were ready. The homeowner-occupants were surveyed at the same time as audit visits whenever possible. The other stakeholder surveys were performed later.

MONITORED SITE DESCRIPTIONS

The general characteristics of the monitored sites were:

Site A1

The home is a detached bungalow in Hantsport, N.S. This was one of Nu-Air's first product installations. Throughout this project, the home was occupied by two adults and two children. The installation report from Nu-Air identified the design heating load as 12.6 kW at an unspecified outdoor temperature. The installation guide reported that EnerGuide for Houses was the basis for the heating-load calculation. This was a non-arms length site.

Site B1

This site was a two-storey, detached home in Windsor Junction, N.S. It was one of the first product installations performed by Kerr. Throughout this project, the home was occupied by two adults. The installation report identified the design heating load as 11.6 kW at –16°C (3.2°F) outdoor temperature. The heating load calculation method used was "F326-H2K" according to the installation report. This was a non-arms length site.

Site C1

This site was a two-storey detached home in St. Catharines, Ont. and was one of Vebteck's first product installations. Throughout this project two adults and three children occupied the home. The installation report did not identify a design heating load. However, a Hot2000 analysis[1] performed before the integrated system was installed estimated the design space heating load at 12.3 kW. This was a non-arms length site.

Site D1

This site in Toronto was a large, two-storey, detached home. It was one of the first product installations performed by Tirino. Two adults and three children, two of whom were teenagers, lived in the home during the project. The home was undergoing significant interior renovations throughout this project and the installation report did not identify a design heating load.

SITE MONITORING

The éKOCOMFORT consortium developed and supplied the monitoring package and data acquisition program for this project, which consisted of:

- Two Kamstrup™ energy meters, each comprising a water-flow meter, two temperature probes and a battery-powered electronics module
- 11 thermocouples
- An in-line electricity meter with pulse output to sub-meter the electricity use
- A fuel-valve timer and isolating relay to monitor burner on–off operation
- Status relays to signal control/operating modes to the data logger
- One Campbell Scientific™ CR10X data logger.

Every 40 days, researchers visited the sites to inspect the installations and retrieve data. During the inspections, the homeowners (if present) were asked whether they had any concerns about their systems. The systems were checked visually for signs of pending problems, leaks and so on. Manual readings were taken from utility billing meters and the electricity sub-meter. In some site visits, researchers took spot measurements of temperatures and flows and did combustion efficiency tests.

MEASUREMENT PROCEDURES

The following measurements were taken at each site:

- **Combustion measurements**
  Taken during each site visit as a check to determine whether the systems had been correctly adjusted when they were commissioned and to track changes in combustion performance over time. The researchers used Testo® hand-held, battery-powered combustion analyzers.
- **Ventilation airflow measurements**
  Taken at the sites a number of times. The design ventilation flow rate for all of the integrated systems was 30 L/s at the continuous setting and 70 L/s at the high ventilation setting. All the units used nominal 125-mm (6-in.) diameter ducts for ventilation supply and exhaust. Some of the installations used flexible ducts.

[1] HOT2000 evaluations of potential installation sites were provided by NRCan (when requested by the manufacturers) to assist them in selecting and qualifying sites for the early installations.

During the project, various techniques and instruments were tried in attempts to obtain accurate and repeatable ventilation flow measurements. Ultimately, an Alnor™ velometer produced flow readings within acceptable limits of those obtained with a pitot-tube traverse using an averaging digital manometer. The velometer became the preferred instrument because it was more robust than the manometer, did not require batteries or power and was simpler to use.

RESEARCH FINDINGS

Monitored sites

Research findings for the monitored sites included the following information:

- **System loads and load distribution**
  An analysis of the daily loads for water heating and space heating at each of the monitored sites with load distribution graphs prepared for each monitored site.
- **Overall thermal efficiency**
  Calculated to not include any off-cycle losses or on-cycle losses that are not captured by the energy meters.
- **Combustion efficiency**
  An indicator of the performance of the system while the burner was operating.
- **Ventilation flow and sensible recovery efficiency**
  To assess the energy recovery performance of the ventilation portions of the integrated systems.

Table 1 summarizes the performance of the integrated systems at each site.

Part load performance analysis

The process of normalizing performance data was used to convert system loads and efficiencies into dimensionless fractions. This allowed performance information to be easily compared with available data for different alternatives.

For heating systems, part-load performance was normalized using the following procedures and terminology:

- Part load ratio (PLR): is the system's average output divided by its full output.
- Part load factor (PLF): is the efficiency divided by the efficiency at full output.

The systems' load and efficiency data for each site was evaluated as follows:

Parameter	Site A	Site B	Site C	Site D
Combustion efficiency (%)[a,b] (at approximately steady-state conditions)	86–88	84–85	90–93	84–86
Overall thermal efficiency (%)[c]	58	72	72	63
Overall part load ratio[d]	0.20	0.29	0.13	0.10
Burner cycles per year[e]	3,520	7,600	N/A[f]	10,000
Average DHW consumption (L/day)	173	272	198	211
Average DHW energy load (kWh/day)	10.3	12.5	11.8	9.1
Sensible recovery efficiency (%)[g]	67	40[h]	N/A[i]	60

a The combustion efficiency or "stack efficiency" measurements from the portable analyzers provide an indication of the system's combustion performance when the system is operating on a steady demand. Unless the burner output can be modulated, this corresponds with the full-load output of the systems.

b No degradation in stack efficiency was observed at any sites during the project

c Calculated over the total monitoring period for each site

d Part load ratio (PLR) is the average system output divided by the specified system capacity of 14 kW

e A typical furnace in a Canadian residential installation will have approximately 8000–9000 cycles per year (based on personal communication with Dr. E. Entchev, ACT, NRCan, 2004)

f Data not available because of a problem with a relay in the monitoring equipment

g Based on measurements taken with the system controls adjusted to provide nominally 30 L/s ventilation flows

h The ventilation system flows were out of balance

i The ventilation system was inoperable because of a control relay failure

Table 1—Performance Summary

- The output (in kW) from the integrated system during a selected time interval was divided by 14 kW to obtain the PLR.
- The calculated efficiency for the same time interval was divided by the previously-measured efficiency with 14 kW output to obtain the PLF.

A scatter plot of the normalized part load characteristics for the integrated systems (shown in Figure 1) was used to incorporate performance data from all of the monitored sites. Each data point

represents several weeks of operation. The line graph in Figure 1 is the default normalized part-load curve for furnaces used in the DOE-2 computer program that models the performance of HVAC equipment.

The part-load heating efficiencies of the integrated systems were reduced by approximately the same amounts as residential furnaces when the systems operated at the same part-load factors.

Figure 1 —Part load factor (PLF) vs part load ratio (PLR) for furnaces and integrated equipment

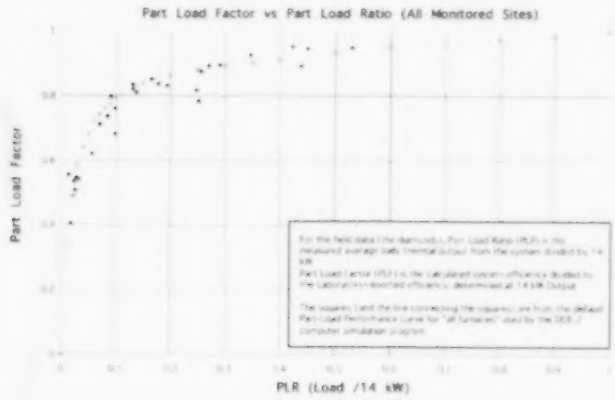

Figure 1 Part load factor (PLF) vs part load ratio (PLR) for furnaces and integrated equipment

AUDIT RESULTS

The audits identified problems at some installations. Examples include:

- Controls to activate the high-speed ventilation mode had not been installed or connected at several sites.
- The ventilation systems were not operational because dampers had not been properly connected. This problem was observed at a few sites.
- At most sites, the ventilation airflows were not balanced within the manufacturers' specifications. This may relate to the manufacturers' unfamiliarity with the efficient variable-speed programmable blower motors that they had all incorporated in their products. The motors had been programmed to obtain the desired flows in a test laboratory using a "constant torque" programming mode. The laboratory motor program was used for the early field installations, but the resulting ventilation airflows were different in the field. Differences in the duct resistances between the laboratory and the field affected the flows as well as the balance between the circulation flow and ventilation flow.

  Some manufacturers now use a more sophisticated constant airflow programming procedure and they provide speed adjustment taps that allow for small adjustments of airflow (± 15%) in the field without reprogramming the motors.
- Two of the integrated products did not operate properly with a commonly available HVAC thermostat. This required upgrades to the controls.
- One system had an intermittent problem with nuisance lockouts that stopped the burner from operating until the safety controls were manually reset. The manufacturer corrected the problem by realigning or replacing a component.
- An in-line, recirculating defrost damper failed to open at two sites, which disabled the product's defrost mechanism and caused imbalanced ventilation flows. Failure at two sites suggests that the damper motor may not be strong enough for this application.

SURVEY RESULTS

Most of the installations were performed at "non-arm's-length" sites, and in many cases the installer was also the manufacturer. This reduced the effectiveness of the surveys because the success and value of advertising and marketing materials in the equipment selection process could not be evaluated at sites of a friendly employee or a relative of the manufacturer. Similarly, the adequacy of the installation support materials and equipment manuals could not be assessed from an installer perspective when the installer was the system designer or manufacturer.

HOMEOWNER SURVEY

Overall, the homeowners were satisfied with the systems and believed that they were benefiting from state-of-the-art equipment. Almost all the homeowners said that they believed that their homes had improved air quality because of the integrated ventilation function of their systems. Many, however, when asked, did not know how to adjust the ventilation rates of their systems.

Two of the system designs incorporated blending valves to limit the delivery temperatures of domestic hot water. Some of the homeowners who had these systems installed said that they would like to obtain hotter water. They were unaware that they could adjust the blending valves to obtain higher outlet temperatures.

An initial, short-term drop in the delivered domestic hot water temperature was mentioned in the homeowner survey at one site. After the homeowners had become accustomed to this, they no longer perceived the temperature fluctuation as a problem.

Because the products installed for this project were prototypes or early production units, full documentation and support materials such as installation manuals and user instructions were generally not available. This was identified as a potential problem by a number of the homeowners.

SURVEY OF OTHER STAKEHOLDERS (BUILDERS AND INSTALLERS)

The surveys indicated:

- Installers would install the equipment (and similar, generic equipment) again in other customers' homes.
- Installers need improved wiring schematics and installation–commissioning instructions.
- One builder commented that although his clients had commented favourably on the even heat from the system and that he would recommend the system to other clients, the integrated system "did not seem as straightforward as conventional single product alternatives." He felt that the new system required more information to use than conventional systems.
- Another builder said that the small footprint, "all-in-one unit with easy access for service" was the feature that appealed to him the most.

CONCLUSIONS

While some, but not all, of the installations were at "arms-length" from the manufacturers the homeowner survey indicated that the users were happy with the products.

Conclusions on equipment performance include:

- The integrated systems that were installed and monitored during this project worked with no major problems (though with some early hiccups) and had no difficulty in providing the required thermal outputs for space heating and water heating. Other conclusions include:
- Site measurements from flue gas efficiency analyzers and other equipment were generally consistent with the laboratory test results for similar loads.
- There was no evidence of any degradation in the combustion performance at any sites.
- Overall, the integrated systems operated at average daily loads between 10 per cent and 29 per cent of their design capacities
- System loads have a significant effect on the overall performance of integrated HVAC systems as well as conventional HVAC equipment. The part-load performance degradation for the integrated systems is similar to published information for conventional HVAC equipment.

Further field trials should use a more simplified monitoring approach. The monitoring packages for this project were complicated and proved to be difficult to install and commission. The data loggers needed to be interconnected with the controls of the integrated systems using isolating relays. Although the interconnect wiring was performed by the manufacturers at all of the monitored sites, the load from the additional relays may have contributed to erratic operation and subsequent failure of a solid-state control board at one site. By comparison, the water-based energy meters proved to be fairly straightforward to install: required no external power source and no interconnection to the system controls. The energy meters operated with no problems throughout the project.

REFERENCE

The ɘKOCOMFORT™ Field Assessment Program. Peter Edwards Co. report to CMHC, 2005

CMHC Project Manager: Bill Semple, Senior Researcher

Consultant: Peter Edwards Company

Housing Research at CMHC

Under Part IX of the *National Housing Act*, the Government of Canada provides funds to CMHC to conduct research into the social, economic and technical aspects of housing and related fields, and to undertake the publishing and distribution of the results of this research.

This fact sheet is one of a series intended to inform you of the nature and scope of CMHC's research.

To find more *Research Highlights* plus a wide variety of information products, visit our website at

www.cmhc.ca

or contact:

Canada Mortgage and Housing Corporation
700 Montreal Road
Ottawa, Ontario
K1A 0P7

Phone: 1-800-668-2642
Fax: 1-800-245-9274

©2006, Canada Mortgage and Housing Corporation
Printed in Canada
Produced by CMHC 18-09-2006

Although this information product reflects housing experts' current knowledge, it is provided for general information purposes only. Any reliance or action taken based on the information, materials and techniques described are the responsibility of the user. Readers are advised to consult appropriate professional resources to determine what is safe and suitable in their particular case. Canada Mortgage and Housing Corporation assumes no responsibility for any consequence arising from use of the information, materials and techniques described.

65245